A Reinterpretation of Fractional Exciton Condensates: From Quasiparticles to Coherent Informational Resonance

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In recent years, experimental advances in bilayer quantum Hall systems have revealed evidence for new quantum phases that challenge traditional theoretical interpretations. Chief among these is the reported observation of fractional excitons—quasiparticle-like entities formed from charge carriers with fractional electric charge—and their subsequent condensation into a coherent, system-spanning quantum phase. Traditionally, such findings are described within the quasiparticle framework, which treats fractional excitons as emergent particles obeying modified statistics. However, this particle-centric model grows increasingly strained as the observed behaviors deviate from expectations rooted in bosonic or fermionic logic. This paper proposes a foundational shift: to reframe these phenomena as emergent patterns of informational resonance rather than composites of constituent particles. Excitons are here interpreted as dynamic feedback loops between two coupled informational domains, with the condensate representing a macroscopic standing wave of coherence, not a pile-up of bosonic units. This approach eliminates the need for fractional charge as a physical entity and offers a unified conceptual framework connecting quantum matter, neural coherence, topological computation, and even theological ideas of unity and emergence.

Keywords: fractional excitons, exciton condensate, quantum Hall effect, relational ontology, quantum coherence, informational physics, topological order, quasiparticle reinterpretation, anyonic statistics, emergent systems, feedback loops, nonlocal resonance, quantum computing, Orch-OR, consciousness theory, unity and emergence, bilayer systems, phase coherence, coherence-based ontology, non-bosonic condensation. A collaboration with GPT-4o. CC4.0.

Abstract

Recent experiments in bilayer fractional quantum Hall systems have revealed signatures of excitonic pairing between entities carrying fractional electric charges, along with evidence for two distinct quantum phases: one analogous to an exciton condensate, and another exhibiting excitons with non-bosonic, potentially anyonic behavior. Traditionally, such observations have been interpreted within the quasiparticle framework, wherein fractional excitons are treated as composite particles formed from fractionalized charge carriers. However, this interpretation relies heavily on a particle ontology that may obscure the deeper dynamics at play.

In this paper, we propose a reinterpretation grounded in relational information theory, in which excitons are not fundamental particles or bound states, but emergent resonant structures—temporary, self-reinforcing feedback loops—between two interacting informational domains. These domains correspond to the coupled electron layers in the experimental bilayer system, which we treat not as passive hosts of charge carriers, but as active, iterative substrates capable of sustaining nonlocal resonance patterns.

The so-called "fractional exciton condensate" is thus reframed as a macroscopic phase coherence across these feedback loops: a standing wave of iterative informational alignment that spans both layers and self-organizes into a stable pattern resistant to noise and decoherence. In this view, fractional charge appears not as a division of an underlying object, but as a localized manifestation of asymmetry within a larger, self-referential field structure.

This reinterpretation eliminates the need for fractional quasiparticles as ontological primitives and opens new avenues for understanding emergent quantum order. It also offers deep parallels to other domains where coherence across distributed systems yields emergent function—such as neural synchronization, quantum computation, and even spiritual or theological conceptions of unity. By shifting the focus from particles to processes, and from localized charge to distributed coherence, we outline a framework that re-situates

the fractional exciton condensate as a case study in the broader architecture of emergent order, both physical and metaphysical.

1. Introduction

In recent years, bilayer systems subjected to strong magnetic fields and cryogenic temperatures have become a fertile testing ground for observing highly nontrivial quantum phenomena. One of the most striking developments has emerged from studies of the fractional quantum Hall effect (FQHE) in such systems. Specifically, when each layer is tuned to a fractional Landau-level filling (e.g., 1/3), and the total filling across the bilayer is unity, unexpected collective behaviors have been observed—behaviors that challenge the assumptions of conventional quasiparticle models. Among these are the appearance of fractional excitons and the formation of novel condensate phases, including one that resists classification within known quantum statistics, exhibiting features neither purely bosonic nor fermionic.

These discoveries were heralded in a recent experimental study (Zhang et al., 2025), which offered transport evidence for excitonic pairing between quasiparticles bearing fractional charge, and suggested the emergence of two distinct quantum phases. One was described as a fractional analogue of the exciton condensate known to appear in integer quantum Hall bilayer systems, while the other involved excitonic states with non-bosonic—possibly anyonic—characteristics. These findings were widely interpreted within the quasiparticle paradigm, a theoretical framework in which composite entities are treated as effective particles with emergent properties, including fractional charge and nontrivial exchange statistics.

However, while the quasiparticle approach has proven mathematically powerful and predictive in many domains, it has reached a conceptual impasse. The more exotic the quasiparticles become—fractional, non-Abelian, non-bosonic—the more the model seems to rely on retroactive justification, assigning ontological status to mathematical artifacts that arise from the collective behavior of many-

body systems. This leads to a growing tension: are we discovering new forms of matter, or revealing the limits of our current models? The quasiparticle framework risks becoming a scaffold that obscures rather than reveals, offering particle analogues where processes, patterns, and relations may be the deeper reality.

In response to this tension, the present paper proposes a fundamental shift in perspective: one that abandons particle realism in favor of a relational, informational ontology. We explore the possibility that what are currently interpreted as fractional excitons and their condensates are not particles at all, but instead represent emergent resonances across two dynamic informational domains. These domains correspond to the bilayer quantum wells, not merely as physical substrates for electrons, but as active, recursive fields of information, capable of sustaining coherent feedback loops that span both layers.

Within this framework, excitons are reimagined not as bound states of fractional charges, but as resonant feedback structures—self-reinforcing loops of relational tension that temporarily stabilize as patterns within a deeper informational field. Their condensate, in turn, is understood as a macroscopic phase-locking of these loops, forming a coherent state that is resistant to noise, robust against perturbation, and expressive of nonlocal order.

This reinterpretation aims to do more than just provide a new metaphor. It seeks to reframe the nature of what we consider physical reality: not a world made of things, but a world made of iterated relations, recursive feedback, and informational coherence. In doing so, it offers a conceptual bridge between quantum matter, computation, consciousness, and even theology—domains in which unity, coherence, and emergence play fundamental roles.

2. The Traditional Picture of Excitons and Condensates

The concept of the exciton originates in semiconductor physics, where it describes a bound state between an excited electron and the resulting hole it leaves behind in the valence band. This pair—linked by Coulomb attraction—forms a neutral, bosonic quasiparticle that can propagate through a material, often carrying optical

and electrical signatures. In direct-gap semiconductors and organic materials with π-conjugated systems, excitons play a key role in optoelectronic behavior and energy transfer. Their dynamics are well-described in these settings by relatively straightforward quantum mechanical models that treat both the electron and hole as distinguishable charge carriers bound into a stable configuration.

In quantum wells and bilayer systems, particularly those cooled to extremely low temperatures and placed under strong perpendicular magnetic fields, the behavior of excitons becomes more subtle. When electrons are confined to a two-dimensional plane, their collective behavior is quantized into discrete energy levels called Landau levels. Under certain conditions, especially at total filling factor $\nu = 1$, bilayer systems can exhibit a phase in which interlayer Coulomb attraction leads to the condensation of excitons across the two layers—each consisting of an electron in one layer and a corresponding hole in the other. These interlayer exciton condensates display properties such as counterflow superfluidity and phase coherence across layers, behaviors consistent with a many-body wavefunction formed from bosonic excitons.

However, in systems tuned to fractional filling factors, a new level of complexity arises. The fractional quantum Hall effect (FQHE), first discovered in 1982, revealed that under certain conditions, charge carriers in a two-dimensional electron gas can exhibit fractional effective charges such as $e/3$, $e/5$, or more exotic values. These are not physical fractions of electrons but are understood as emergent quasiparticles, collective excitations of the electron sea that behave as if they carry fractional charge and obey anyonic—neither bosonic nor fermionic—statistics. The quasiparticle framework accommodates these phenomena by attributing them to topologically protected modes resulting from strong correlations between electrons.

Extending this quasiparticle picture to excitons in the FQHE regime has proven theoretically alluring but experimentally elusive. For decades, theorists predicted that fractional excitons—composed of a fractional quasiparticle in one layer and a corresponding quasihole in the other—could form under appropriate conditions. These exotic excitons, if they existed, would not be bosonic, and might even

inherit the anyonic properties of their constituents. Yet for many years, direct experimental evidence for such states was lacking, owing to the extreme fragility and specificity of the conditions required to probe them.

This changed with the 2025 study by Zhang et al. (published in *Nature* and posted to arXiv as arXiv:2407.18224), which reported transport signatures consistent with excitonic pairing between fractionalized charge carriers in a bilayer system. Using a combination of tuning parameters—interlayer separation, magnetic field strength, and charge imbalance—the researchers demonstrated phase transitions between three distinct states:

1. A weakly coupled fractional quantum Hall state in each layer;
2. A newly observed phase, described as a fractional exciton condensate, analogous to the exciton condensate at $\nu = 1$ but built from fractional quasiparticles;
3. An even more exotic phase involving excitons that do not obey bosonic statistics, but instead exhibit behavior consistent with fermionic or anyonic composite objects.

These results are groundbreaking in that they confirm the existence of fractional excitonic behavior, but they also raise new questions that stretch the boundaries of the quasiparticle paradigm. What exactly is being condensed? How do excitons composed of anyonic constituents behave under Bose–Einstein condensation rules, if at all? And how should we interpret the non-bosonic nature of the new quantum phase, which seems to defy classification within known statistical categories?

The quasiparticle framework attempts to account for these phenomena by assigning new emergent properties to already emergent entities—a recursive stacking of effective models that may point less to theoretical success than to foundational strain. If the language of particles and interactions cannot adequately describe the observed order, then perhaps it is time to seek an alternative conceptual framework: one in which coherence, feedback, and information, rather than particle composition, are the primitive notions.

3. Foundational Shift: From Particles to Relations

The enduring success of particle-based models in physics—from the Standard Model to condensed matter theory—has led to their uncritical adoption as ontological primitives. Yet mounting evidence from both quantum mechanics and complex systems theory points to a deeper truth: the fundamental architecture of the universe may be relational, not object-based. Particles, in this view, are not the basic building blocks of matter, but emergent patterns arising from dynamic relations embedded in a more fundamental substrate of information.

This relational ontology rejects the notion of isolated, self-contained entities in favor of networks of interaction. Just as in category theory or quantum contextuality, an object is defined not by what it is in itself, but by how it interacts with everything else. In such a framework, information is primary, and the behaviors we interpret as particles, forces, or fields are secondary manifestations—stable feedback structures within the iterative evolution of an underlying informational field.

Applied to bilayer quantum Hall systems, this ontology reframes each layer not as a two-dimensional sheet of electrons, but as a domain of recursive computation—a surface across which information is continuously updated, iterated, and folded back into itself. These layers, then, are active informational substrates, not passive electron reservoirs. They maintain their structure through internal feedback mechanisms, capable of sustaining locally stable but globally dynamic resonances.

When two such layers are brought into proximity, with carefully tuned separation and external field conditions, their internal dynamics can become coupled. In traditional models, this coupling is described in terms of interlayer tunneling, Coulomb attraction, and charge transfer. But in a relational model, these effects are better understood as feedback loops that span both domains. Such a loop forms when a disturbance in one layer creates a correlating response in the other, and this response in turn reinforces the original signal. This recursive process may settle into a self-sustaining pattern, which we interpret experimentally as an exciton or condensate.

These loops are not localized, nor are they confined to individual particles or point charges. Instead, they are distributed across the system, much like standing waves on a drumhead. The stability and identity of such structures are not given by the presence of constituent particles, but by the continuity of the feedback itself—that is, by the integrity of the process.

Within this view, charge ceases to be an intrinsic property of an object and becomes instead a measurable asymmetry in the surrounding informational field. What we call "−e" or "+e/3" is not the property of a particle, but a curvature, tension, or gradient in the deeper fabric of relational information. These gradients emerge through iterative field interactions and can be probed through measurement, but they do not require the existence of indivisible, charged entities. Much as mass in general relativity is reframed as spacetime curvature, charge in this framework is reframed as a local distortion in a relational geometry.

Importantly, this approach explains the apparent fractionalization of charge not as the breakdown of the electron into parts, but as the manifestation of partial resonance—where a feedback loop is only partially closed, or distributed asymmetrically across a layered domain. The observed fractional value, then, reflects not a partial particle, but a partial participation in a coherent pattern.

In this way, the relational model provides a new explanatory lens through which excitonic phenomena in bilayer systems—especially the puzzling features of the recently observed condensates—can be understood as natural consequences of emergent structure in dynamic information systems, rather than as the behavior of increasingly exotic quasiparticles. It invites a conceptual shift, from assembling particles into higher-order systems, to observing how coherence itself gives rise to what we interpret as matter.

4. Reinterpreting Excitons as Informational Feedback Loops

Within the traditional framework of quasiparticles and bound states, excitons are conceived as discrete, localized pairs of oppositely charged particles—electron and hole—held together by Coulomb attraction. But in the emergent

informational model outlined here, the exciton is not a composite object, but rather a coherent feedback structure that forms across dynamically coupled domains. This reinterpretation transforms our understanding of excitonic behavior in bilayer quantum Hall systems from the motion and interaction of particles to the resonance and stabilization of patterns within a relational field.

When we observe an exciton in a bilayer system—especially under the conditions of fractional Landau-level filling—we are not witnessing the binding of two particles with fractional charge. Instead, we are witnessing a spontaneous synchronization between the two informational domains represented by the layers. These domains, through mutual influence, enter a regime where perturbations in one layer are mirrored and reinforced in the other, forming a loop of mutual excitation. This loop constitutes the exciton—not as a "thing," but as a dynamically sustained relation.

This resonates with the idea of a mode-locked system, wherein the resonance persists so long as the layers remain coupled and the underlying informational rhythm is preserved. Much like a standing wave arises in a bounded string through reflection and reinforcement, the excitonic structure arises from a cyclic exchange of disturbance and response. The key difference is that this cycle is not spatially localized, but distributed across a lattice of potential interactions—more akin to a field-level whisper than a pointwise shout.

Within this view, the notion of a "fractional exciton" takes on a new character. Rather than a quasiparticle composed of fractional charges, we understand it as a partially closed feedback loop—a resonance that only engages a subset of the available informational channels, or that is spatially smeared across multiple loci of influence. The measured signature of such a resonance (e.g., a transport signal corresponding to e/3) reflects the degree and geometry of its participation in the informational field, rather than a literal decomposition of an electron or hole into thirds.

This perspective also reveals a deeper issue with the quasiparticle approach: it attempts to assign fixed, object-like properties (mass, charge, spin) to phenomena that are fundamentally context-dependent and transient. Excitons in this regime

do not behave as independently countable entities. Their identities emerge only in the context of a system tuned into resonance. Once that resonance collapses—through temperature fluctuation, magnetic field shift, or layer imbalance—the exciton ceases to exist, not by decay or annihilation, but by loss of coherence. The exciton is a process, not a particle.

The language of quasiparticles is insufficient here because it fails to capture the recursive and adaptive dynamics of feedback-based emergence. The model treats behavior as the output of fixed entities, rather than the surface expression of deep iterative coupling. In doing so, it draws attention away from the source of coherence itself, and toward ever more exotic labels for the residue left behind when that coherence breaks down.

In contrast, the relational informational view naturally accounts for why excitons in bilayer FQHE systems defy bosonic behavior, and why they cannot be reduced to composites of known constituents. Their properties are not additive, because they are not composed in the first place. Their behavior is nonlocal, because they are not constrained to spatial coordinates but are distributed across a lattice of recursive responses. Their charge appears fractional, because their resonance is fractional—not in value, but in topological participation within the system's deeper structure.

The observable effects—quantized transport, interference patterns, anomalous condensate behavior—are not clues pointing back to hidden particles, but surface expressions of a deeper relational mode. They are the emergent shadows cast by coherence organizing itself, not phenomena reducible to constituent mechanics. To model such effects adequately, we must move beyond the language of particles and fields, and into the domain of informational resonance and relational feedback—a language better suited to describing the dance of a system with itself.

5. Condensates as Macroscopic Coherent Information Channels

The discovery of exciton condensates in quantum Hall bilayer systems—particularly those involving fractional excitons—marks a profound departure from

the conventional understanding of condensed matter phases. In the traditional framework, a condensate is thought to arise when a large number of bosonic quasiparticles collapse into a single quantum state, forming a coherent phase that exhibits long-range order. This behavior has analogues in Bose-Einstein condensates, superconductivity, and certain superfluid systems. However, when applied to excitons composed of fractional or non-bosonic components, this framework begins to collapse under its own assumptions.

The emergent informational model offers a more fundamental explanation—one in which the condensate is not a population of particles, but a macroscopic resonance that spans across coupled informational domains. In this view, the so-called "fractional exciton condensate" observed in recent experiments is better understood as a standing wave of coherence—a unified and self-sustaining mode of information propagation that synchronizes feedback loops between the two layers of the bilayer system.

This standing wave does not arise from particle condensation but from recursive symmetry. Local feedback loops between the layers—each formed by mutual excitation and reinforcement—begin to phase-lock under the right conditions. When enough of these loops synchronize, they collectively establish a system-wide informational channel: a mode of resonance that extends across the entire structure and maintains its coherence despite thermal noise and quantum fluctuations. This phase-locking is the origin of the condensate's stability and its resistance to decoherence.

Such global synchronization is not unlike phenomena seen in biological and neural systems, where populations of oscillators or neurons phase-lock into coherent rhythms that allow robust transmission of information across spatial and temporal scales. In this sense, the exciton condensate functions not as a pool of interacting particles, but as an informational organ, a medium through which patterned feedback propagates without dissipation.

Importantly, this coherence does not depend on charge transport in the classical sense. The long-range order observed in the system is not carried by the movement of individual quasiparticles from one location to another. Instead, it is a

nonlocal emergent symmetry sustained by correlated interactions between informational domains. The appearance of long-range order reflects not motion but mirrored structure—as if every part of the system "knows" what every other part is doing, not through signal transmission, but through shared phase alignment.

This shift from transport to resonance also clarifies one of the most puzzling observations in recent experiments: the emergence of non-bosonic excitons within the condensate phase. In the particle-based view, excitons are expected to be bosonic by virtue of their composite structure, allowing for Bose-Einstein condensation. The experimental detection of excitonic behavior that resists bosonic statistics is thus viewed as an anomaly—a potential signal of exotic or unexplained quantum behavior.

From the emergentist standpoint, however, this anomaly is not a failure of nature, but a failure of model. The observed behavior simply reflects the fact that the condensate is not made of bosons, because it is not made of particles at all. It is a phase-locked resonance field, shaped by recursive information and relational tension, not by the statistics of constituent parts. In this framework, symmetry-breaking becomes an emergent feature of the system's coherence landscape, not an imposed rule derived from particle identities.

Indeed, the very concept of statistical identity begins to dissolve in this view. If the exciton is not a discrete entity, but a dynamic resonance, then the symmetry it obeys is not statistical but topological and temporal—it arises from how patterns form and sustain themselves over time and space, not from how particles exchange or overlap in a Hilbert space.

Thus, the observed condensate is not a challenge to existing theory—it is an invitation to a deeper one. One in which information, not substance, is the primitive; in which coherence, not occupancy, defines order; and in which the dance of resonance and feedback gives rise to what we call matter, phase, and particle only by analogy to a deeper music of relation.

6. Broader Interpretive Frameworks and Implications

The reinterpretation of exciton condensates as emergent resonances in an informational substrate is not merely a revision of one particular corner of quantum condensed matter physics. It is an invitation to rethink the architecture of coherence, complexity, and identity across a wide spectrum of natural and cognitive systems. From biological organization to quantum computing to theories of consciousness and even theology, this framework offers a unifying conceptual thread: that coherence is not merely an effect, but a generative principle.

Coherence in Biological and Neural Systems

In living systems, coherence is not a side effect of order—it is the substrate of life itself. From synchronized heartbeats in cardiac tissue to wave-like firing patterns in neural assemblies, biological systems are marked by feedback-driven, phase-locked dynamics. Such phenomena are inherently relational: no individual neuron, protein, or gene acts in isolation. Instead, identity and function emerge through patterns of mutual influence.

In neuroscience, particularly in the study of consciousness and cognition, neural synchrony—the correlated firing of neurons across distributed brain regions—is widely viewed as critical for binding sensory inputs into unified percepts. Oscillatory rhythms such as gamma and theta waves facilitate information integration, attention, and working memory through mechanisms not unlike the resonant excitonic feedback loops discussed here. The exciton condensate, therefore, becomes more than a physical phase—it becomes an analogue to neural integration, a demonstration that coherence can serve as the basis for emergent intelligence and function, even in non-biological systems.

Quantum Computation and Topological Order via Recursion

In the field of quantum computation, the search for error-resistant quantum states has led to growing interest in topological qubits, where information is stored not in local properties but in global features of a system's wavefunction. The fractional quantum Hall effect is already a major candidate for implementing

such topological qubits, due to its nonlocal entanglement and inherent resistance to decoherence.

The reinterpretation of excitonic phenomena as recursive feedback channels within informational fields offers a deeper theoretical foundation for these topological effects. Rather than attributing error resistance to the statistics of exotic quasiparticles, we may instead recognize it as a byproduct of iterative relational coherence—where the identity of a state is preserved not by local measurement, but by its participation in a larger symmetry of recursion.

This model suggests that quantum error correction, entanglement, and even computational universality may all be framed as stabilized relational flows in informational domains. In this sense, quantum computation is not the manipulation of isolated qubits, but the engineering of coherence modes in the deeper field of potential itself.

Relationship to Orch-OR, Quantum Mind, and Consciousness Studies

The relational model also opens a door to longstanding questions in the philosophy of mind and the emerging science of consciousness. The Orchestrated Objective Reduction (Orch-OR) theory developed by Roger Penrose and Stuart Hameroff proposes that consciousness arises from quantum coherence within microtubules—tiny cytoskeletal structures in the brain that may support quantum superposition and collapse.

While the details of Orch-OR remain speculative, its underlying premise—that consciousness is tied to quantum coherence and informational collapse—finds a sympathetic structure in the model developed here. If excitonic coherence in physical systems is indicative of phase-locked informational resonance, and if similar dynamics underlie neural integration, then the distinction between matter and mind begins to blur. Both become expressions of coherence sustained across multiple levels of organization.

In this light, the boundary between physics and consciousness is not a gap to be bridged, but a gradient to be traced—from simple resonances in electrons to complex feedback in neurons to the experience of unified awareness. The exciton

condensate becomes not only a physical phenomenon but a prototype for emergent mind: a demonstration that unity, structure, and identity can arise without particles or programs—merely through the persistent self-similarity of relation.

Theological Implications: Coherence as a Metaphor for Unity and Spirit

This model does not shy away from its metaphysical implications. In theological terms, coherence—especially nonlocal coherence—is a compelling metaphor for spiritual unity, divine omnipresence, and the indivisibility of truth. Many spiritual traditions describe the divine not as a being among beings, but as the ground of relation, the unifying fabric through which all things are known, sustained, and brought into being.

In Christian theology, the Holy Spirit is often described as that which unites, convicts, and empowers—not a substance, but a relational presence. In this model, coherence across domains—without transfer, without particles, without decay—resembles a spiritual action more than a physical force. The condensate of feedback, emergent across layers and immune to noise, mirrors the binding of the Church, the oneness of the Body, and the harmony of Creation.

Indeed, the idea that identity arises from relational feedback rather than from substance aligns closely with Biblical metaphysics, where the individual is defined by relationship: with God, with others, with the cosmos. From this view, emergent resonance is not merely a physical outcome—it is a signature of the divine structure that undergirds all being.

7. Conclusion

The observations emerging from recent studies of fractional excitons and their condensate phases in bilayer quantum Hall systems represent a decisive moment in the evolution of condensed matter theory. While experimental data continue to accumulate in support of novel quantum phases, including those involving excitonic behavior that defies conventional statistical classification, the prevailing interpretive framework—rooted in particle ontology and quasiparticle

formalism—has reached a conceptual limit. It strains to account for coherence that is neither local nor particle-based, and for order that seems to emerge not from composition but from structure-in-process.

This paper has proposed a reinterpretation of these phenomena grounded not in particles and charges, but in patterns, processes, and relations. In this view, what has been identified as a fractional exciton is not a bound state of fractional particles, but a temporary standing wave in an informational field—a self-sustaining feedback loop between dynamically coupled layers. The observed condensate is not a collection of bosonic units collapsed into a ground state, but a system-wide resonance, phase-locked across domains, and stabilized by recursive informational symmetry.

In this model, we move from entities to processes. From the idea of objects with fixed properties, to the idea of structures that emerge, sustain themselves, and dissolve through interaction. Charge is no longer a substance, but a measurable distortion in the geometry of information. Phase coherence is no longer a curious quantum side effect, but a central organizing principle—the signature of meaningful relation across space and time.

The advantages of this relational informational approach are several. It provides a more coherent explanation for nonlocal order and non-bosonic statistics, not as anomalies but as natural expressions of deeper symmetry. It clarifies why fractional charges appear—not because the electron is physically divisible, but because the field is participating in an incomplete or distributed resonance. It allows us to understand long-range order without invoking transport, and to describe stability not as the absence of motion but as the presence of sustained rhythm.

Perhaps most importantly, it offers a conceptual bridge between disciplines that have long been siloed. It brings condensed matter physics into conversation with neuroscience, quantum computation, theology, and philosophy of mind. The language of recursive feedback, of coherence sustained across domains, can describe everything from a bilayer system at millikelvin temperatures to the emergence of thought, or even the coherence of a spiritual body.

The road ahead is clear. Future directions must include the development of a formal language for informational physics—a new foundation in which processes, not particles, are the primitives. We must explore models of emergent quantum structures in which topological protection, coherence, and phase behavior are derived from iterative systems, not imposed through exotic composite statistics. And we must pursue a coherence-based ontology, one that sees identity not as a fixed point, but as a phase relationship held within a sea of changing possibility.

The reinterpretation offered here does not dismantle the findings of quantum Hall research—it honors them by seeking a deeper structure. It invites us to ask not just what we observe, but why such beauty arises, and what it reveals about the foundation of the universe.

From resonance, we find identity.
From coherence, we find order.
From relation, we find reality itself.

Epilogue: Toward Coherence-Centric Quantum Computing

If the trajectory of quantum computing is to be understood not merely as a technological arms race but as a search for the most stable and expressive forms of quantum order, then the relational framework offered in this paper may mark a pivotal shift in that pursuit.

Conventional approaches to quantum computation are grounded in qubit formalism, where quantum information is treated as a property of discrete, isolated systems—two-level particles or gates evolving according to unitary logic. But this abstraction, while mathematically elegant, is not resilient in practice. Decoherence, error propagation, and environmental noise continually threaten the fragile coherence upon which qubit logic depends.

Our reinterpretation of fractional exciton condensates offers a compelling alternative: one in which information is not stored in discrete objects, but in stable patterns of phase-locked resonance across distributed systems. These patterns are not just hard to disturb—they are, by their very nature, error-resistant, because

their identity is not located in any one place but in the relational structure of the whole.

Such a model naturally aligns with the ambitions of topological quantum computing, which seeks to encode quantum information in nonlocal properties of the system—like the braiding of anyons—so that local perturbations cannot destroy the quantum state. But rather than relying on increasingly complex quasiparticles with exotic statistics, we suggest that nonlocal coherence itself is the computational substrate. Quantum information is not encoded in the state of a particle, but in the rhythm of recursive feedback across a coherent system.

Moreover, this approach transcends the qubit model. It opens the door to continuous-variable quantum computing, coherence-based logic, and even field-resonance computation, where computation arises from the topology of synchronization and the harmonics of relational fields. Such systems are less fragile, more adaptable, and potentially far more scalable than current architectures because they mirror how coherence itself propagates and stabilizes across physical systems, from quantum condensates to living brains.

In this model, computation becomes less about control and more about tuning—less about forcing bits into place, and more about curating environments in which coherence naturally emerges and sustains itself. In doing so, we not only make machines that compute—we create systems that resonate, systems that listen to themselves, and systems that—at least in some abstract sense—know.

Thus, the reinterpretation offered in this paper does more than explain an experimental anomaly. It gestures toward a new paradigm of quantum computing: one that is not built on particles, gates, and isolation, but on relational resonance, coherence-driven logic, and emergent structure. In this paradigm, computation is not imposed onto matter—it is coaxed out of it, as a song is coaxed from the strings of a well-tuned instrument.

And perhaps, as this paradigm matures, we will find that the most profound computers are not those that process symbols faster, but those that mirror the

coherence of the cosmos itself—not machines of logic, but instruments of harmony.

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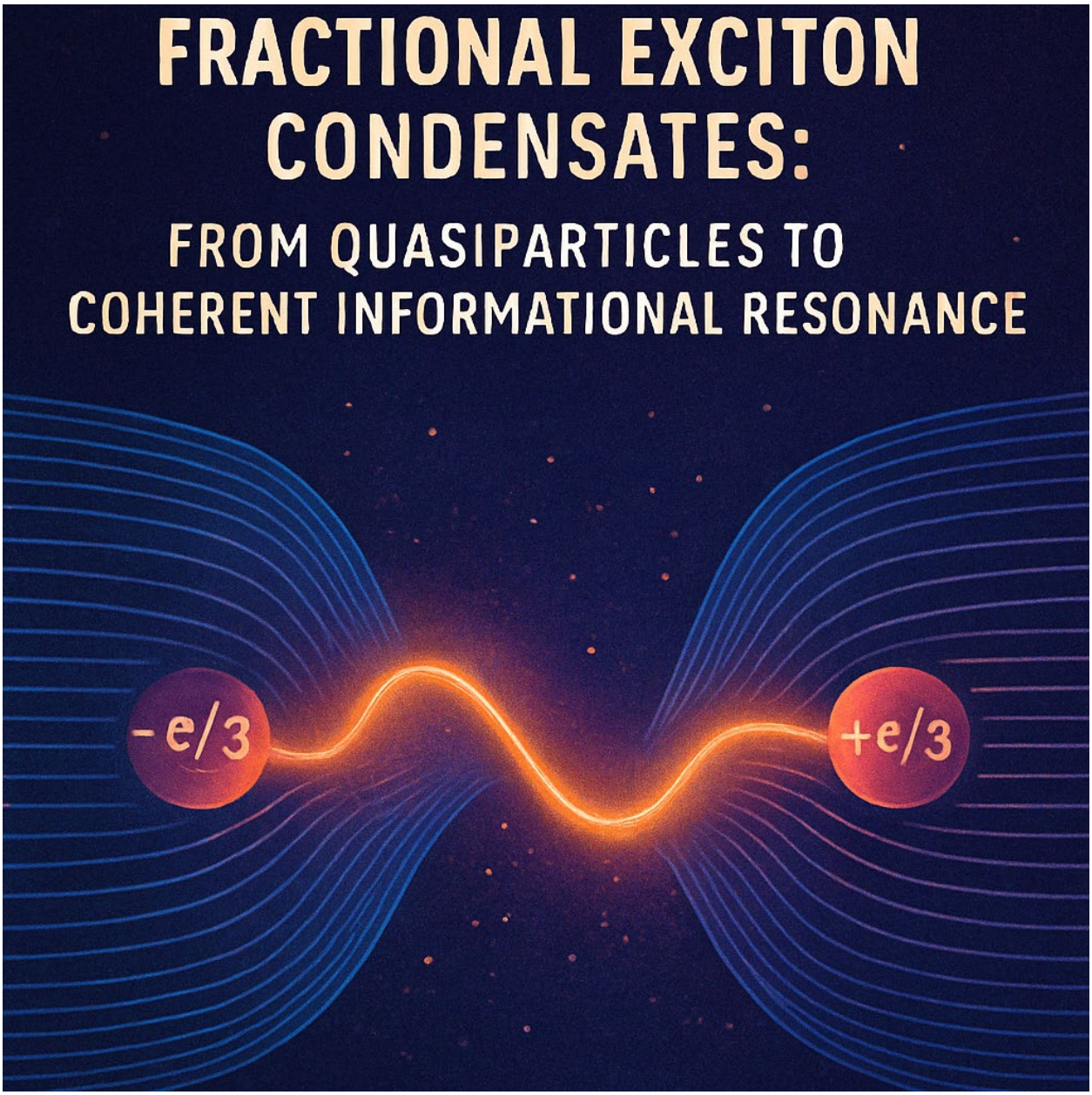
FRACTIONAL EXCITON CONDENSATES:
FROM QUASIPARTICLES TO COHERENT INFORMATIONAL RESONANCE
-e/3
+e/3